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(71) Applicant:
Murata Manufacturing Co., Ltd.
Nagaokakyo-shi Kyoto-fu 617-8555 (JP)

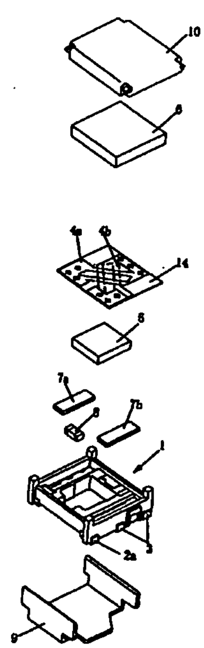
(72) Inventors:
- Shinmura, Satoru,
Murata Manufacturing Co. Ltd.
Nagaokakyo-shi, Kyoto-fu 617-8555 (JP)
- Okada, Takekazu,
Murata Manufacturing Co. Ltd.
Nagaokakyo-shi, Kyoto-fu 617-8555 (JP)
- Makino, Toshihiro,
Murata Manufacturing Co. Ltd.
Nagaokakyo-shi, Kyoto-fu 617-8555 (JP)
- Nakada, Takao,
Murata Manufacturing Co. Ltd.
Nagaokakyo-shi, Kyoto-fu 617-8555 (JP)

(74) Representative:
Schoppe, Fritz, Dipl.-Ing.
Schoppe, Zimmermann & Stöckeler
Patentanwälte
Postfach 71 08 67
81458 München (DE)

(54) Nonreciprocal circuit device and communication device using same

(57) In the structure in which a substrate (14) is provided with first and second center electrodes (4a, 4b), and is disposed between a ferrite sheet (5) and a magnet (6) , solder resist films are provided on the surfaces of the substrate (14). The magnet (6) and the center electrodes (4a, 4b) are separated from each other by means of the solder resin films, whereby the conductor loss, caused by high frequency current flowing in the magnet (6), is suppressed. Thus, the insertion loss of the nonreciprocal circuit device is reduced.

FIG. 1



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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to a nonreciprocal circuit device such as an isolator, a gyrator, or the like to operate in a microwave band or the like, and a communication device including the same.

2. Description of the Invention

[0002] Nonreciprocal circuit devices to operate in a microwave band or the like are disclosed in U.S. Patent No.4016510, Japanese Unexamined Patent Application Publication No. 52-134349, Japanese Unexamined Patent Application Publication No. 58-3402, Japanese Unexamined Patent Application Publication No. 9-232818, and Japanese Unexamined Patent Application Publication No. 8-8612.

[0003] In each of the above-mentioned nonreciprocal circuit devices, center electrodes intersecting each other at a predetermined angle are provided on a ferrite sheet, and a static magnetic field is applied to the ferrite sheet. A nonreciprocal characteristic is presented by rotating the polarization plane of a high frequency magnetic field generated by the center electrodes, based on the Faraday's rotation principle, utilizing the ferrimagnetic characteristic of the ferrite sheet.

[0004] In such a nonreciprocal circuit device containing first, second and third center electrodes as disclosed in Japanese Unexamined Patent Application Publication No. 8-8612, the matching impedance of the third center electrode has a reactance component, and the impedance depends on the frequency. Accordingly, the frequency range where a good nonreciprocal characteristic can be obtained is narrow. That is, when the nonreciprocal circuit device is used as an isolator, the isolation characteristic inevitably becomes narrow.

[0005] The inventors of the present invention has made intensive investigation and experiment in order to provide a nonreciprocal circuit device having a good nonreciprocal characteristic in a wide band. In the investigation, the inventors have found the cause by which the insertion loss is deteriorated in a wide band. In particular, in a conventional nonreciprocal circuit device , a high frequency current flows through a permanent magnet (hereinafter, referred to as a magnet briefly), and power is consumed, due to the electric resistance of the magnet. This is cause for increase of the insertion loss.

SUMMARY OF THE INVENTION

[0006] Accordingly, it is an object of the present invention to provide a nonreciprocal circuit device having a nonreciprocal characteristic in a wide band and a low insertion loss, and a communication device including the same.

[0007] According to the present invention, there is provided a nonreciprocal circuit device which comprises a first center electrode of which one of the ends is connected to an input terminal, and the other end is grounded, a second center electrode intersecting the first center electrode in insulation state between the electrodes, one end of the second center electrode being connected to an output terminal, the other end thereof being grounded, a ferrimagnetic member provided in adjacent to the first and second center electrodes, a magnet for applying a static magnetic field to the ferrimagnetic member substantially perpendicular to the ferrimagnetic member, a first capacitor of which one of the ends is connected to the input terminal and the other end is grounded, a second capacitor of which one of the ends is connected to the output terminal, and the other end is grounded, and an insulation spacer provided between the magnet and the first or second center electrode, whereby power consumption, caused when a high frequency magnetic field, generated by the center electrodes, passes through the magnet so that a high frequency current flows in the magnet, can be suppressed.

[0008] With this structure, the center electrodes are prevented from contacting closely with the magnet, and coupling between the high frequency magnetic field generated in the first and second electrodes and the magnet is weakened. Thus, the conductor loss, attributed to the high frequency current induced in the magnet, can be reduced.

[0009] Preferably, the first and second center electrodes comprise conductor patterns formed on the opposite sides of a substrate, respectively, and resist films are formed on the surfaces of the conductor patterns. The resist films are used as the insulation spacers.

[0010] A resistor to be connected between the input terminal and the output terminal may be mounted onto the substrate having the center electrodes. With this structure, the mounting structure of the resistor can be simplified, and the configuration of the isolator becomes simple.

[0011] Also preferably, the conductor patterns each comprise a metal foil having a thickness of at least 30 μm, and the resist films have a thickness of at least 50 μm. Thereby, the conductor loss, caused by the center electrodes themselves, can be suppressed. Moreover, the conductor loss caused by the magnet can be efficiently reduced.

[0012] Moreover, an insulation film may be bonded to the magnet. The insulation film is used as the insulation spacer between the magnet and the center electrodes.

[0013] Furthermore, the intersection angle between the first and second center electrodes may be a predetermined angle between 90° and 100° inclusive.

Thereby, a desired isolation characteristic can be obtained.

[0014] Preferably, the ferrimagnetic member has a substantially rectangular parallelepiped shape. Thereby, the center electrodes are arranged in the diagonal directions of the ferrimagnetic member. Thus, the long center electrodes can be efficiently arranged. That is, the nonreciprocal circuit device of the present invention, even though the ferrimagnetic member is small in size, has a low loss characteristic.

[0015] Also preferably, the capacitances of the first and second capacitors are substantially the same. Thereby, even if the inductances of the first and second electrodes has a difference, a desired isolation characteristic can be obtained by setting the difference between the phase of a transmission signal in the forward direction from the input terminal to the output terminal and the phase of a transmission signal in the reverse direction from the output terminal to the input terminal at approximately 180°.

[0016] Also preferably, the first and second center electrodes, the ferrimagnetic member, the magnet, and the first and second capacitors are surrounded by yokes to be shielded, respectively, the yokes constituting a magnetic circuit for applying the static magnetic field, and the yokes have a ground potential. With this structure, the first and second center electrodes and the capacitors, have a ground potential together with the yokes to be shielded.

[0017] Furthermore, preferably, an insulator layer is provided between the yoke and the center electrode. Thereby, the yoke is separated from the center electrode, so that high frequency current generated in the yoke is suppressed, the Q value is enhanced, and the insertion loss is reduced.

[0018] Also preferably, plural earth terminals are provided, at least two of the earth terminals and the input terminal are provided in one of the sides of the case, and at least two of the remaining earth terminals and the output terminal are provided in the other side of the case. Thereby, the ground connection is enhanced, so that unnecessary inductance or static capacitance components are suppressed, directly-reached waves from the input terminal to the output terminal are decreased, and the band width (the bandwidth indicating a low insertion loss characteristic) is widened.

[0019] According to the present invention, there is provided a communication device which includes the above-described nonreciprocal circuit device. For example, the nonreciprocal circuit device is provided in the output section of an oscillation circuit, the input section of a filter, or the like to form the communication device.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020]

Fig. 1 is an exploded perspective view of an isolator according to a first embodiment of the present invention;

Fig. 2 is a cross section of a major part of the isolator;

Fig. 3 is a circuit diagram of the isolator;

Figs. 4A and 4B are circuit diagrams each showing the operational principle of the isolator;

Fig. 5 is an equivalent circuit diagram of the isolator;

Fig. 6 is a graph showing examples of the insertion loss characteristics of the isolator and a conventional isolator;

Fig. 7 is a cross section of a major part of an isolator according to a second embodiment of the present invention;

Fig. 8 is an exploded perspective view of an isolator according to a third embodiment of the present invention;

Fig. 9 is a cross section of a major part of the isolator;

Figs. 10A, 10B, 10C, and 10D are graphs showing the frequency characteristics of the isolators;

Figs. 11A, 11B, 11C, and 11D are graphs showing the frequency characteristics of the isolator as a comparative example for the isolator of the third embodiment;

Figs. 12A and 12B are graphs showing the relation between the thickness of a solder resist film and the insertion loss and the relation between the thickness of a center electrode and the insertion loss; and

Figs. 13A and 13B are block diagrams each showing the configuration of a major part of a communication device according to a fourth embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0021] The structure of an isolator according to a first embodiment of the present invention will be described with reference with Fig. 1 to 6.

[0022] Fig. 1 is an exploded perspective view of the isolator. A resin case 1 is formed by insert molding, using input-output terminals 2a and 2b and an earth terminal 3, One 2a of the input-output terminals is shown. The other input-output terminal 2b and the other two earth terminals 3 are formed on the left-back side face in Fig. 1 of the resin case 1. The inner ends of the two input-output terminals 2a and 2b are exposed on the inner bottom surface of the resin case 1. The isolator includes a ferrite sheet 5 made of a ferrimagnetic material, capacitors 7a and 7b having capacitor electrodes

provided on the upper and lower surfaces thereof, a chip resistor 8, and a lower yoke 9 made of a ferromagnetic material 9. The capacitors 7a and 7b, and the chip resistor 8 are disposed in the case 1. The ferrite sheet 5 is placed in the concavity defined by the case 1 and the lower yoke 9. A first center electrode 4a and a second center electrode 4b are formed so as to intersect with each other at a predetermined intersection angle between 90° and 100° on the upper and under faces of an insulation sheet 14. One ends of the two center electrodes 4a and 4b are led out via through-holes to the under side in Fig. 1. The other ends of the center electrodes 4a and 4b are connected to each other via through-holes. The substrate 14 is formed by patterning a high frequency circuit substrate, which is an insulation substrate having copper foils bonded to both of the sides thereof. A magnet 6 is disposed to apply a static magnetic field to the center electrodes 4a and 4b and the ferrite sheet 5. An upper yoke 10 is formed from a ferromagnetic material. An upper yoke 10 is made of a ferromagnetic material. The magnet 6 is attached to the inner face (the lower face in Fig. 1) of the upper yoke 10.

[0023] The respective parts of the isolator are formed as described above. The ferrite sheet 5 is accommodated in the case 1. The capacitors 7a and 7b are placed therein, and the substrate 14 is disposed in such a manner that the capacitors 7a and 7b are sandwiched between the substrate 14 and the case 1. The chip resistor 8 is mounted to the under face of the substrate 14 in such a manner as to connect the ends of the first and second center electrodes 4a and 4b to each other. The lower yoke 9 is attached to the underside of the case 1. The upper yoke 10 having the magnet 6 attached thereto is made to cover the case 1. Thus, an isolator as a whole is formed.

[0024] Fig. 2 is a cross section of an major part of the above-described isolator. As seen in Fig. 2, solder resist films 11 are formed on both of the whole faces of substrate 14, respectively. Thus, the resist films 11 lie over the surfaces of the first and second center electrodes 14, respectively. Even though the magnet 6 is disposed closely to the substrate 14, the magnet 6 and the first center electrode 4a are separated from each other by the thickness of the solder resist film 11. Also, the center electrode and the upper yoke are further separated from each other by the layer of the solder resist film. Similarly, the ferrite sheet 5 and the second center electrode 4b are separated from each other at least by the thickness of the solder resist film 11. The thickness of the above-mentioned solder resist film 11 is at least 50 μm, and that of the respective first and second center electrodes is at least 30 μm.

[0025] Fig. 12A shows the relation of the distance between the magnet 6 and the center electrode 4a, to the insertion loss (IL). When the distance between the magnet 6 and the center electrode 4a is small, a high frequency current flows in the magnet 6, caused by an eddy current, so that power is consumed, due to the electric resistance of the magnet 6. Furthermore, the magnet 6 has a large dielectric loss tangent (tan δ). Thus, when the magnet 6 is positioned closely to the center electrode 4a, the dielectric loss is increased. Moreover, the smaller the distances between the yoke 9 and 10 and the center electrodes 4a and 4b are , the larger amount of high frequency current flows, caused by an eddy current, so that power is consumed, due to the electric resistances of the yokes. These cause the insertion loss to increase.

[0026] For the purpose of decreasing the loss, the center electrodes and the magnet, and also, the center electrodes and the yokes are separated from each other by means of the solder resist films, respectively. In the isolator having an outer size of 5 mm × 5 mm × 2 mm, the insertion loss (IL) is changed with the thickness of the solder resist film, as shown in Fig. 12A. Like this, the larger the thickness of the solder resist film is, the smaller the insertion loss (IL) becomes, and is rapidly saturated when the thickness exceeds about 50 μm. When the thickness of the solder resist film is 50 μm, the insertion loss is 1.3 dB. In general, the insertion loss required for isolators having the above outer size is up to 1.3 dB. Therefore, the thickness of each of the above-described solder resist films is set at 50 μm or more.

[0027] Fig. 12B shows a relation between the thickness of each center electrode and the insertion loss (IL). In this case, the thickness of the solder resist film is set at 50 μm, as seen in the above description. The larger the thickness of the center electrode is, the smaller the electric resistance becomes (the Q value increases), so that the insertion loss is reduced. The insertion loss (IL) changes with the thickness of the center electrode being varied, as shown in Fig. 12B. Like this, the larger the thickness of the center electrode is, the smaller the insertion loss (IL) becomes, and is rapidly saturated when the thickness exceeds about 30 μm. When the thickness of the center electrode is 30 μm, the insertion loss is 1.3 dB. Moreover, as described above, the required insertion loss is generally up to 1.3 dB. Accordingly, the thickness of each of the center electrodes 4a and 4b is set at 30 μm or larger. For the purpose of reducing the height of the isolator as much as possible, the thickness of each of the center electrodes 4a and 4b is set at approximately 40 μm.

[0028] Fig. 3 is a circuit diagram of the above-described isolator. In the circuit of this example, the ferrite sheet 5 has a disk-shape. As shown in Fig. 3, the first center electrode 4a is connected between the input terminal 2a and the earth terminal 3, the second center electrode 4b is connected between the output terminal 2b and the earth terminal 3, a capacitor C1 is connected between the input terminal 2a and the earth terminal 3, a second capacitor C2 is connected between the output terminal 2b and the earth terminal 3, and moreover, a resistor R is connected between the input terminal 2a and the output terminal 2b.

[0029] Figs. 4A and 4B are circuit diagrams illustrat-

ing the operational principle of the above-described isolator. Fig. 5 is an equivalent circuit diagram of the isolator.

[0030] In Figs. 4A and 4B, the arrows indicate the directions of high frequency magnetic fields under the center electrodes. Now, the transmission of a signal in the forward direction will be described. At both of the ends of the resistor R, the same phases and the same amplitudes are produced, so that no current flows through the resistor R. An input signal from the input terminal 2a as it is output from the output terminal 2b.

[0031] The entrance of a signal in the backward direction will be described. As seen in Fig. 4B, the direction of the high frequency magnetic field transmitting through the ferrite sheet 5 is reverse to that shown in Fig. 4A. Thus, 180° out-of-phase signals are produced at both of the ends of the resistor R, and power is consumed in the resistor R. Accordingly, ideally, no signal is output from the input terminal 2a.

[0032] Practically, the difference between phases at both of the ends of the resistor, produced when a signal is transmitted in the forward direction and when a signal enters in the reverse direction, is changed, depending on the intersection angle between the above-described center electrodes 4a and 4b and the rotational angle of a polarization plane, attributed to the Faraday rotation. Accordingly, the intensity of an outer magnetic field and the intersection angle between the center electrodes 4a and 4b are determined in such a manner that a small insertion loss and a high isolation characteristic can be obtained. Ordinarily, the intensity of a magnetic field applied to the ferrite sheet is 0.09 to 0.17 (T). Therefore, by setting the intersection angle between the center electrodes 4a and 4b to be in the range of 90° to 100°, a small insertion loss and a high isolation characteristic can be obtained.

[0033] In respect to the above-described operation, the phase difference between a signal S12 (propagation signal in the reverse direction) and a signal S21 (a transmission signal in the forward direction) becomes 180°, by removing the resistor R from the equivalent circuit diagram of Fig. 5. If the inductances L1 and L2 of the center electrodes 4a and 4b have a difference, the phase difference departs from 180°. However, by providing capacitors C1 and C2, and setting the static capacitances to be equal to each other, the above-mentioned departure of the phase difference can be prevented. Accordingly, even if the difference in amplitude between S21 and S12 is about 0.2 dB, the capacitances of the capacitors 7a and 7b (C1, C2) are set to be substantially equal to each other with the difference of ± 0.05 (5%) in order to set an isolation of at least 30 dB. Thereby, even if the sizes of the formed patterns of the first and second center electrodes are dispersed, a good isolation characteristic can be obtained.

[0034] Fig. 6 is a graph showing the insertion loss characteristic A of the isolator of this embodiment in comparison with that B of a conventional isolator, in which no solder resist film is provided on the surface of a substrate. As described above, by separating the center electrode from the magnet by means of the solder resist film formed on the surface of the substrate, the insertion loss can be reduced in a wide frequency range.

[0035] Next, the structure of an isolator according to a second embodiment of the present invention will be described with reference to Fig. 7.

[0036] Fig. 7 is a cross section of a major part of the isolator of the second embodiment. The cross section is shown correspondingly to that of the first embodiment of Fig. 2. In this embodiment, an insulation film 13 is bonded to the surface on the substrate side of the magnet 6. Moreover, no solder resist films are formed on the surfaces of the center electrodes 4a and 4b provided on both of the sides of the substrate 14, respectively. With this structure, the magnet 6 and the center electrode 4a can be separated from each other at least by the insulation film 13, so that the loss of power caused by the magnet 6 can be reduced. That is, the insertion loss characteristic can be improved. In the structure of Fig. 7, solder resist films may be formed on the surfaces of the substrate 14 having the center electrodes 4a and 4b formed thereon. Thereby, the magnet 6 and the center electrode 4a can be separated from each other by a predetermined distance by utilizing the thickness of the solder resist film and that of insulation film 13.

[0037] Next, the structure of an isolator according to a third embodiment of the present invention will be described with reference to Figs. 8 to Fig. 11A, 11B, 11C, and 11D.

[0038] Fig. 8 is an exploded perspective view of the isolator. A resin case 1 is formed by insert molding together with input-output terminals and earth terminals 3. One 2b of the input-output terminals is shown. The other input-output terminal and the other two earth terminals are provided on left-rear side in Fig. 8 of the resin case 1. The inner ends of the two input-output terminals are exposed on the inner bottom surface of the case 1. In the case 1, capacitors 7a and 7b having capacitor electrodes provided on the upper and lower surfaces thereof, and a chip resistor 8 are disposed, and a ferrite sheet 5 formed from a ferrimagnetic material is accommodated in the concavity defined by the case 1 and a lower yoke. Center electrodes 4a and 4b formed from copper foils, respectively, are provided so as to elongate from the upper face to the under face of the ferrite sheet 5 and intersect each other at a predetermined intersection angle in the diagonal directions of the ferrite sheet 5. A magnet 6 is provided to apply a static magnetic field to the center electrodes 4a and 4b and the ferrite sheet 5. An upper yoke 10 is formed from a ferromagnetic material. The magnet 6 is bonded to the inner face (the under face in Fig. 8) of the yoke 10. An insulation spacer 12 made of a resin sheet having a predetermined thickness separates the magnet 6 from the center electrodes 4a and 4b. A lower yoke 9 is formed from a ferromag-

netic material.

[0039] The respective parts of the isolator are formed as described above. The capacitors 7a and 7b and the chip resistor 8 are mounted in the case 1. In addition, the center electrodes 4a and 4b together with the ferrite sheet 5 are mounted therein. In this state, the capacitors 7a and 7b are sandwiched between the electrodes in the case 1 and the center electrodes 4a and 4b. Then, the lower yoke 9 is attached to the underside of the case 1. The upper yoke 10 having the magnet 6 previously attached thereto is made to cover, whereby the isolator as a whole is formed.

[0040] Fig. 9 is a cross section of a major part of the above-described isolator. In this figure, the lower and upper yokes 9 and 10 are omitted. As shown in Fig. 9, the center electrode 4a and the center electrode 4b are insulated from each other by means of the insulation film 15. The insulation spacer 12 is disposed so as to be interposed between the ends of the center electrodes 4a and 4b and the magnet 6, so that the magnet 6 and the center electrode 4b are kept at a predetermined interval.

[0041] The each input-output impedance of the isolators is changed, depending on the thickness of the ferrite sheet and the length of the center electrodes. However, by matching the impedance with the input-output line impedance, loss caused by mismatching of the impedances can be reduced. This embodiment uses the ferrite sheet 5 having such a thickness that the bottom surface of the ferrite sheet 5 is positioned above that of the case 1. The thickness of the case 1 may be reduced, so that the ground electrode portion of the center electrodes, provided on the under surface of the ferrite sheet, is brought into close contact with the lower yoke.

[0042] Figs. 10A, 10B, 10C, and 10D are graphs showing the frequency characteristics of the above-described isolator. Figs. 11A, 11B. 11C, and 11D are graphs showing the frequency characteristics of an isolator as a contrast. Figs. 10A and 11A show the input reflection characteristics (S11), Figs. 10B and 11B show the transmission characteristics (S21), Figs. 10C and 11C show the isolation characteristics (S12), and Figs. 10D and 11D show the output reflection characteristics (S22).

[0043] In the isolator having the characteristics graphed in Figs. 10A, 10B, 10C, and 10D, the intersection angle of the two center electrodes is 90°, and the resistor is connected between the input-output terminals as shown in Fig. 5. On the other hand, the isolator having the characteristics graphed in Figs. 11A, 11B, 11C, and 11D includes three center electrodes with an intersection angle of 120°, and one end of the third center electrode is grounded via a resistor. The sized of the ferrite sheets employed in the two isolators are the same.

[0044] When the two center electrodes are used, and the intersection angle is smaller than 120°, as described above, a good isolation characteristic can be obtained in a wide band. According to the present invention, in the isolator containing such two center electrodes and having an intersection angle of the electrodes of less than 120°, the insertion loss is reduced. Thereby, a small insertion loss in a wide frequency range and a good isolation characteristic in a wide band can be obtained.

[0045] Next, the configuration of a communication device will be described with reference to Fig. 13.

[0046] One of the above-described different types of isolators is provided in the oscillation output section of an oscillator such as VCO or the like, as shown in Fig. 13A, so that a reflection wave from a transmission circuit connected to the output section of the isolator is prevented from entering the oscillator. Thereby, the oscillation stability of the oscillator is enhanced.

[0047] Moreover, as shown in Fig. 13B, an isolator is provided in the input section of a filter to be used for matching. Thereby, a constant impedance filter is formed. This circuit is provided in a transmission reception circuit section to form a communication device.

[0048] In the above-described embodiments, the nonreciprocal circuit device is used as an isolator. When a gyrator (nonreciprocal phase shifter) having the characteristic that the phase lags are different, depending on transmission directions between two ports is formed, the chip resistor 8 (the resistor R in the equivalent circuits of Figs. 3 and 4)is removed.

[0049] According to the present invention, closely contact of the center electrode to the magnet can be avoided, so that coupling of a high frequency magnetic field caused by the first or second center electrode to the magnet can be weakened, and loss caused by a high frequency current induced in the magnet can be reduced.

[0050] Moreover, the insulation spacers can be simply provided by covering the substrate having the conductor patterns formed thereon with the resist films. Accordingly, the whole structure of the nonreciprocal circuit device can be simplified, and the number of parts can be reduced.

[0051] Also, the mounting structure of the resistor can be simplified, and the isolator can be easily configured.

[0052] Moreover, the conductor loss caused by the center electrodes themselves can be suppressed, and also, the conductor loss caused by the magnet can be efficiently reduced. Thus, the insertion loss can be efficiently reduced as a whole.

[0053] Preferably, the insulation film bonded to the magnet is used as the insulation spacer between the magnet and the center electrode. Thus, a structure for holding the insulation spacer becomes simple, and the assembly can be easily performed.

[0054] Furthermore, low insertion loss and high isolation characteristics can be obtained.

[0055] The center electrodes can be arranged in

the diagonal directions of the ferrimagnetic member. That is, the long center electrodes can be efficiently arranged. Accordingly, even if the ferrimagnetic member is small in size, a low loss characteristic can be obtained. The nonreciprocal circuit device can be formed by a method including cutting a ferrimagnetic material having a sheet or rectangular parallelepiped shape. The production of the device becomes simple.

[0056] Moreover, even if the inductances of the first and second center electrodes have a difference, the difference between the phase of a transmission signal in the forward direction from the input terminal to the output terminal and the phase of a transmission signal in the reverse direction from the output terminal to the input terminal becomes 180°. Thus, a desired isolation characteristic can be obtained.

[0057] Furthermore, the first and second center electrodes and the capacitors, together with the yoke, have a ground potential, to be shielded. Therefore, generation of a spurious component can be suppressed.

[0058] The yoke is separated from the center electrode, such that high frequency currents generated in the yoke are suppressed, the Q value is enhanced, and the insertion loss is reduced.

[0059] In addition, the ground connection can be intensified, and unnecessary inductance or static capacitance components can be suppressed. Thus, advantageously, directly-reached waves from the input terminal to the output terminal are reduced, and the bandwidth becomes broad.

[0060] Moreover, by providing the nonreciprocal circuit device in the output section of an oscillation circuit or in the input section of a filter, a communication device having a low loss and stable characteristics can be obtained.

Claims

1. A nonreciprocal circuit device comprising a first center electrode (4a) of which one of the ends is connected to an input terminal (2a), and the other end is grounded, a second center (4b) electrode intersecting the first center electrode (4a) in insulation state between the electrodes, one end of the second center electrode (4b) being connected to an output terminal (2b), the other end thereof being grounded, a ferrimagnetic member (5) provided in adjacent to the first and second center electrodes (4a, 4b), a magnet (6) for applying a static magnetic field to the ferrimagnetic member (5) substantially perpendicular to the ferrimagnetic member (5), a first capacitor (7a) of which one of the ends is connected to the input terminal (2a) and the other end is grounded, a second capacitor (7b) of which one of the ends is connected to the output terminal (2b), and the other end is grounded, and an insulation spacer provided between the magnet (6) and the first or second center electrode (4a, 4b).

2. A nonreciprocal circuit device according to claim 1, wherein the first and second center electrodes (4a, 4b) comprise conductor patterns formed on the opposite sides of a substrate (14), respectively, and the insulation spacer comprises a resist film (11) formed on the surface of the conductor pattern.

3. A nonreciprocal circuit device according to claim 2, wherein a resistor (8) to be connected between the input terminal (2a) and the output terminal (2b) is mounted onto the substrate (14).

4. A nonreciprocal circuit device according to claim 1, 2 or 3, wherein the conductor patterns each comprise a metal foil having a thickness of at least 30 μm, and the resist film (11) has a thickness of at least 50 μm.

5. A nonreciprocal circuit device according to claim 1, wherein the insulation spacer comprises an insulation film bonded to the magnet (6).

6. A nonreciprocal circuit device according to one of claims 1 to 5, wherein the intersection angle between the first and second center electrodes (4a, 4b) is a predetermined angle between 90° and 100° inclusive.

7. A nonreciprocal circuit device according to one of claims 1 to 6, wherein the ferrimagnetic member (10) has a substantially rectangular parallelepiped shape.

8. A nonreciprocal circuit device according to one of claims 1 to 7, wherein the capacitances (C1, C2) of the first and second capacitors (7a, 7b) are substantially the same.

9. A nonreciprocal circuit device according to one of claims 1 to 8, wherein the first and second center electrodes (4a, 4b), the ferrimagnetic member (5), the magnet (6), and the first and second capacitors (7a, 7b) are surrounded by yokes (9, 10) to be shielded, respectively, said yokes (9, 10) constituting a magnetic circuit for applying the static magnetic field, and the yokes (9, 10) have a ground potential.

10. A nonreciprocal circuit device according to claim 9, wherein insulator layers are provided between the yokes (9, 10) and the center electrodes (4a, 4b), respectively.

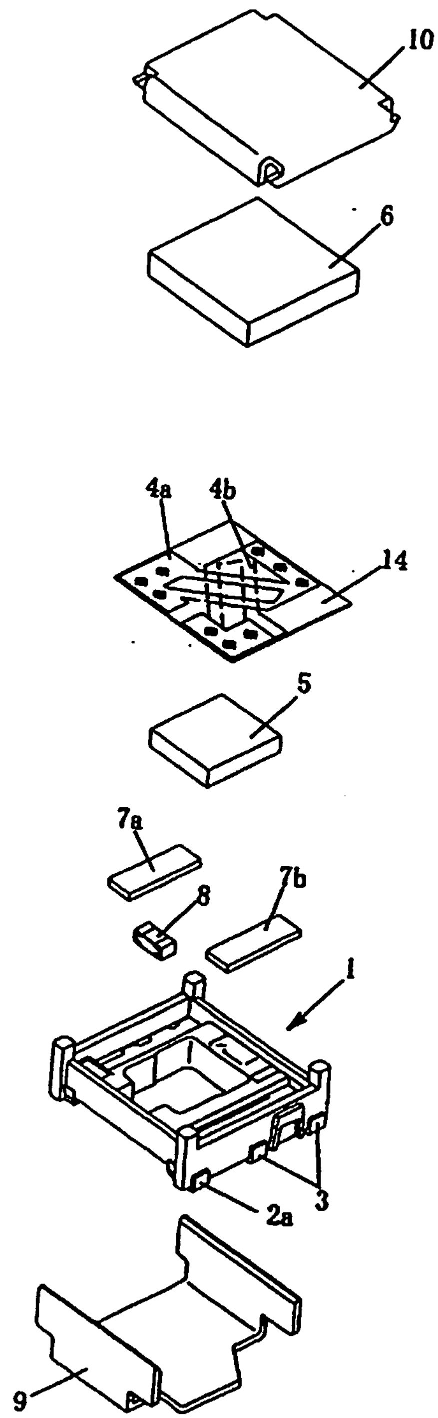
11. A nonreciprocal circuit device according to one of claims 1 to 10, wherein plural earth terminals (3) are provided, at least two of the earth terminals (3) and the input terminal (2a) are provided in one of the sides of the case (1), and at least two of the

remaining earth terminals (3) and the output terminal (2b) are provided in the other side of the case (1).

12. A communication device including the nonreciprocal circuit device in accordance to one of claims 1 to 10.

13. A nonreciprocal circuit device according to one of claims 1 to 11, wherein the intersection angle between the first and second center electrodes (4a, 4b) is 90°.

FIG. 1



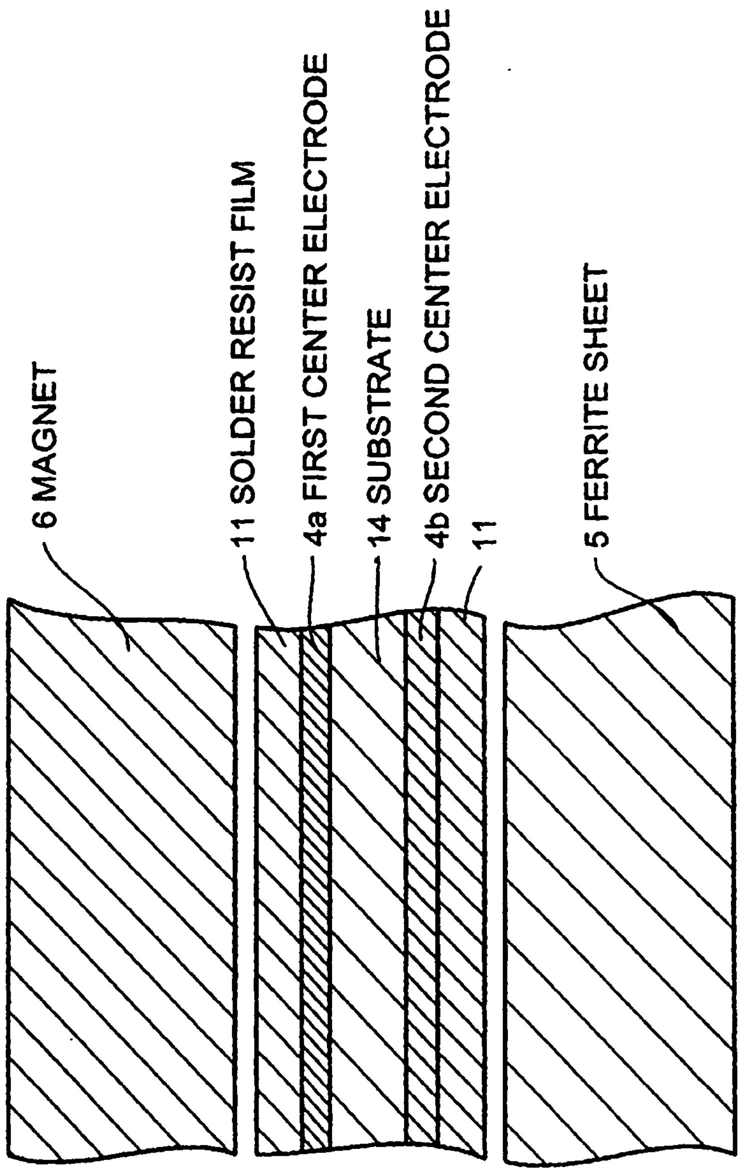
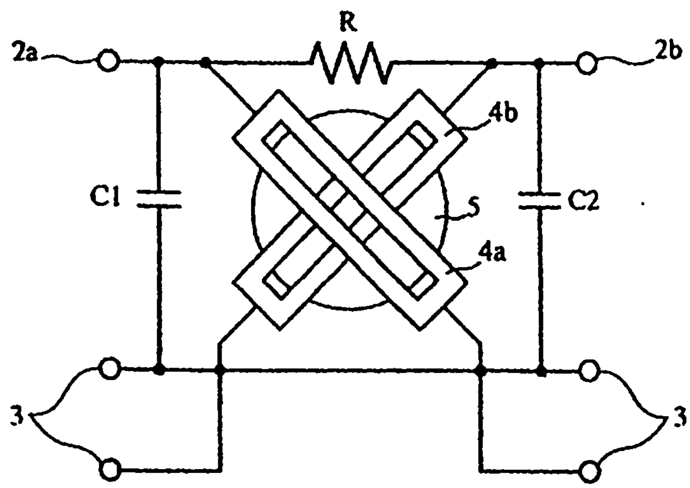

6 MAGNET
11 SOLDER RESIST FILM
4a FIRST CENTER ELECTRODE
14 SUBSTRATE
4b SECOND CENTER ELECTRODE
11
5 FERRITE SHEET

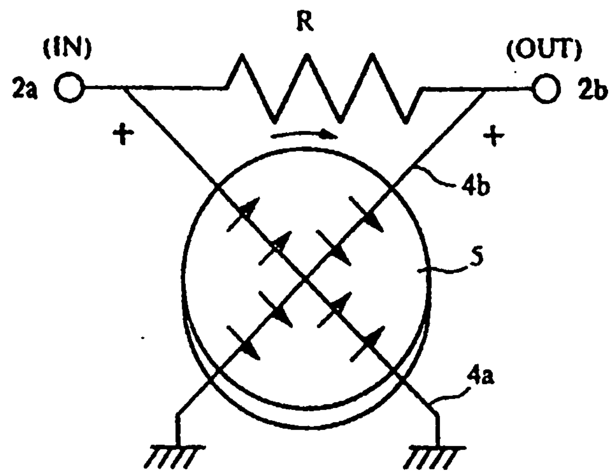
FIG. 2

FIG. 3



0 degree Phase difference
between both ends of resistor

FIG. 4A



180 degrees phase difference
between both ends of resistor

FIG. 4B

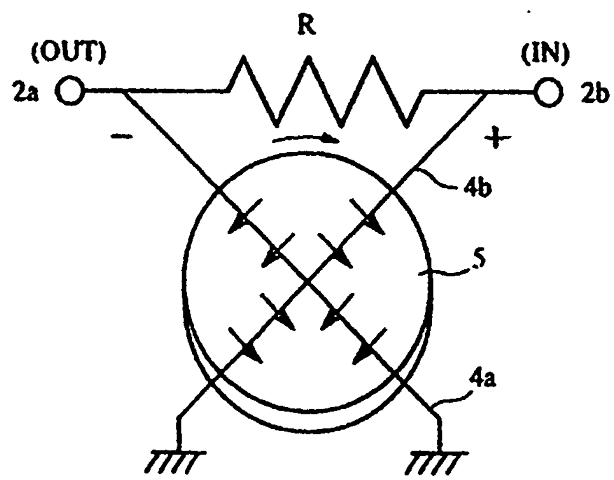


FIG. 5

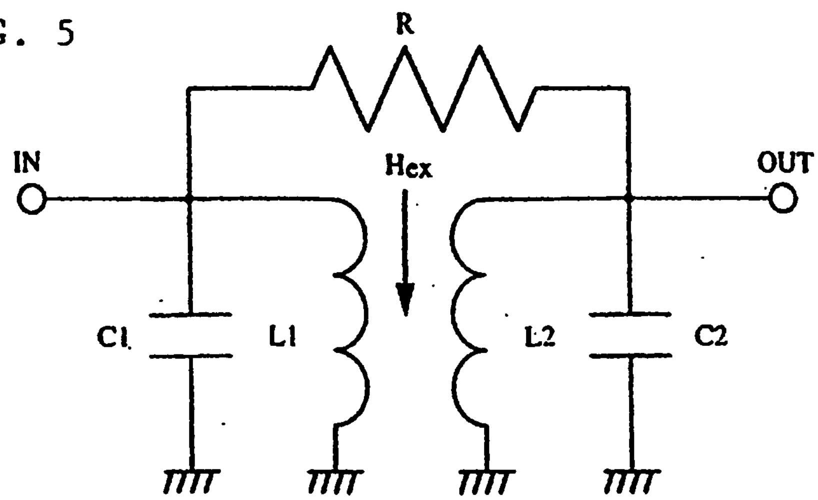


FIG. 6

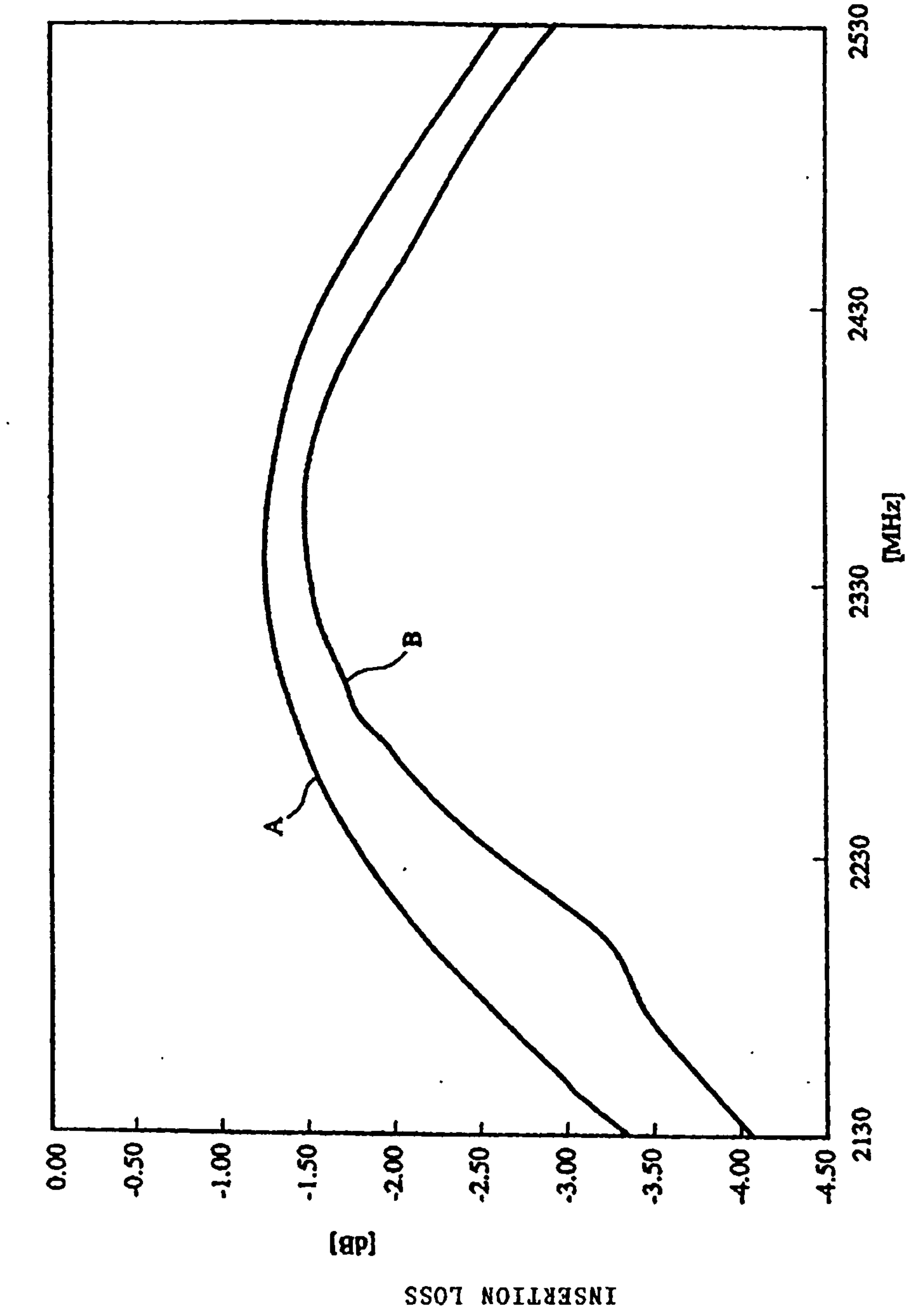

0.00
-0.50
-1.00
-1.50
-2.00
-2.50
-3.00
-3.50
-4.00
-4.50
[dB]
INSERTION LOSS
2130
2230
2330
2430
2530
[MHz]
FREQUENCY
A
B

FIG. 7

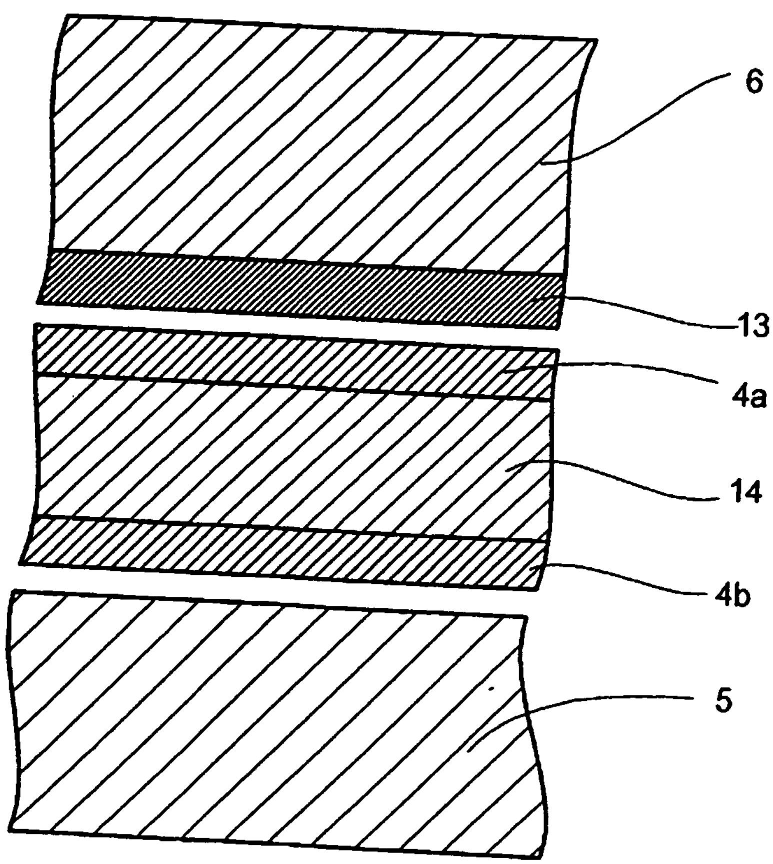


FIG. 8

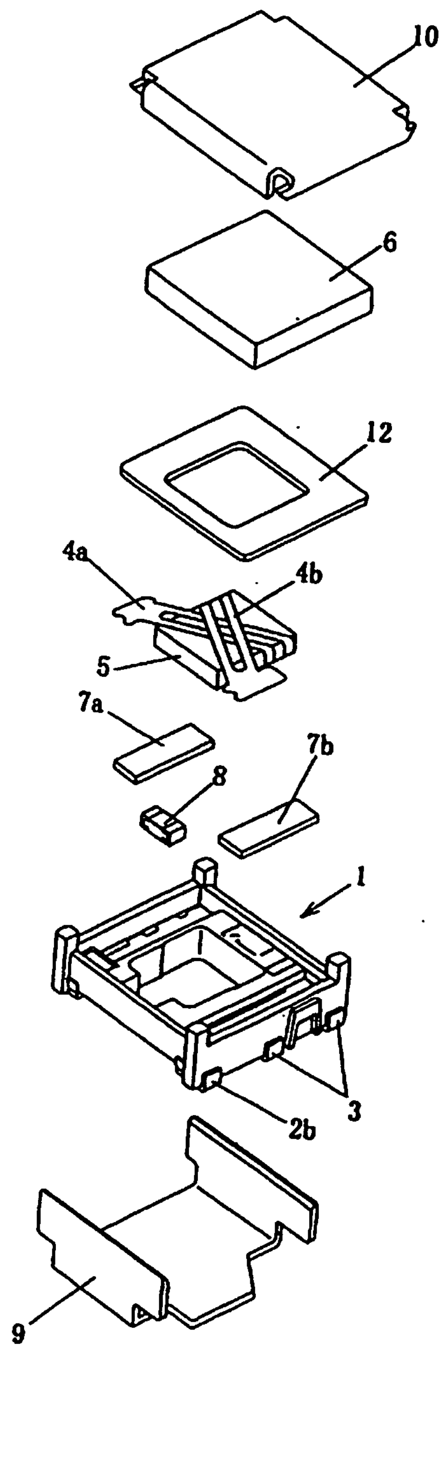
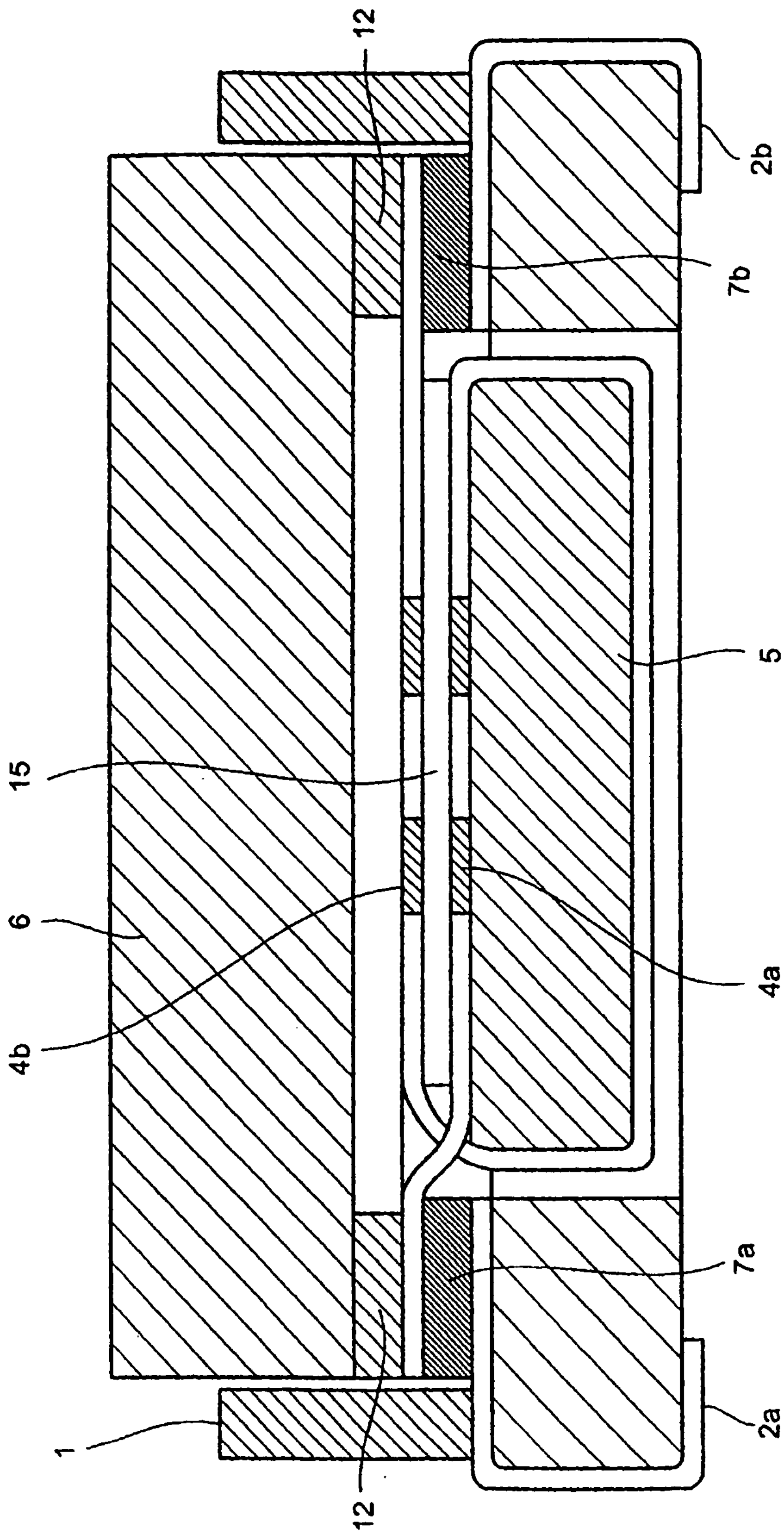


FIG. 9



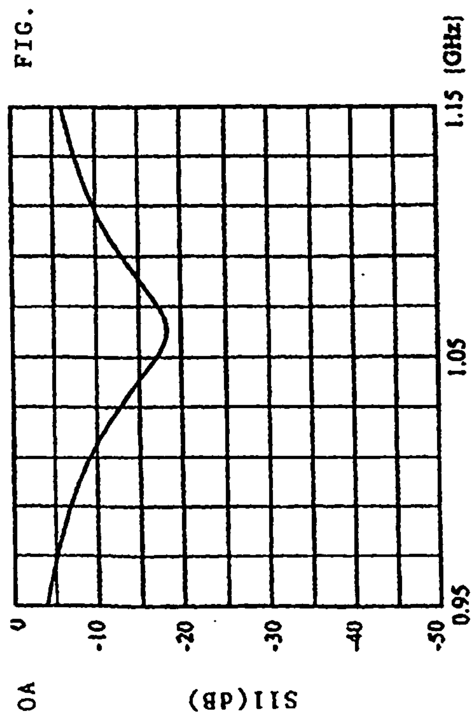


FIG. 10A

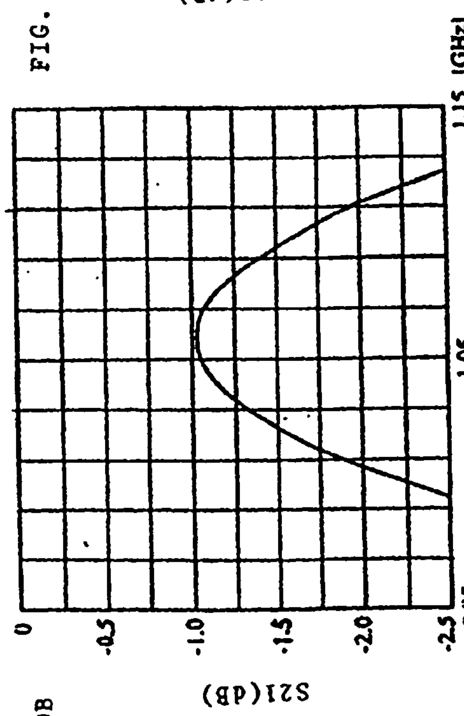


FIG. 10B

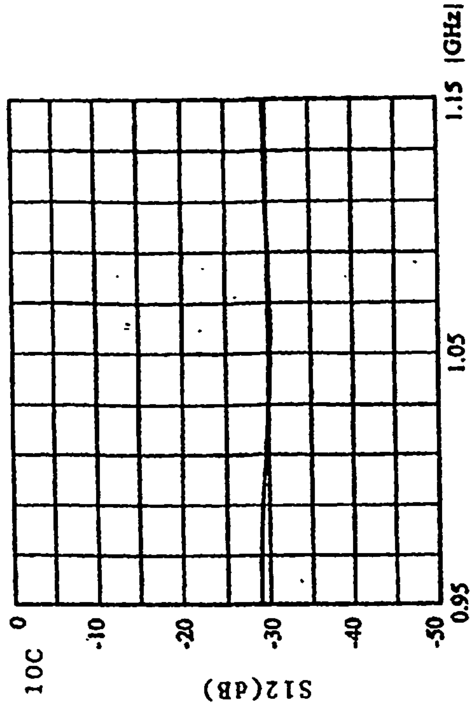


FIG. 10C

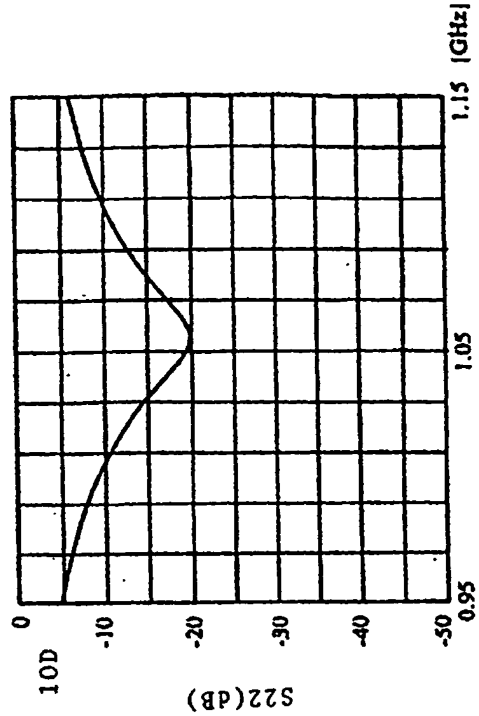


FIG. 10D

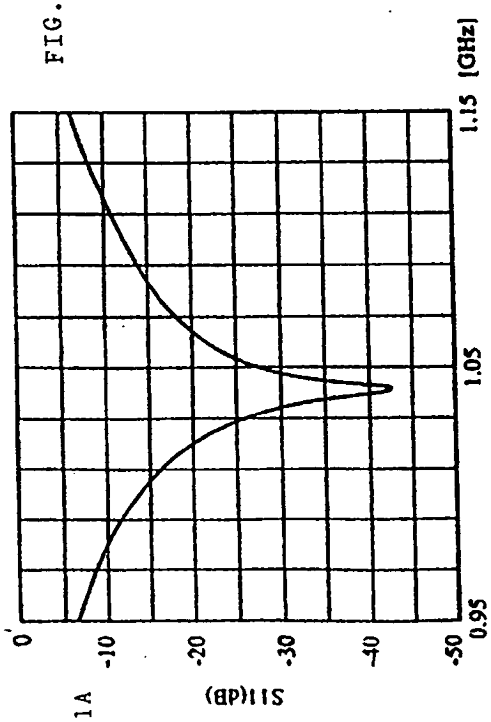


FIG. 11A

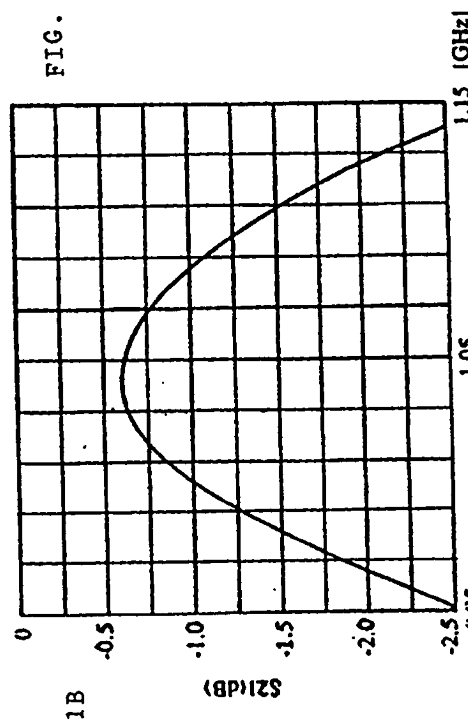


FIG. 11B

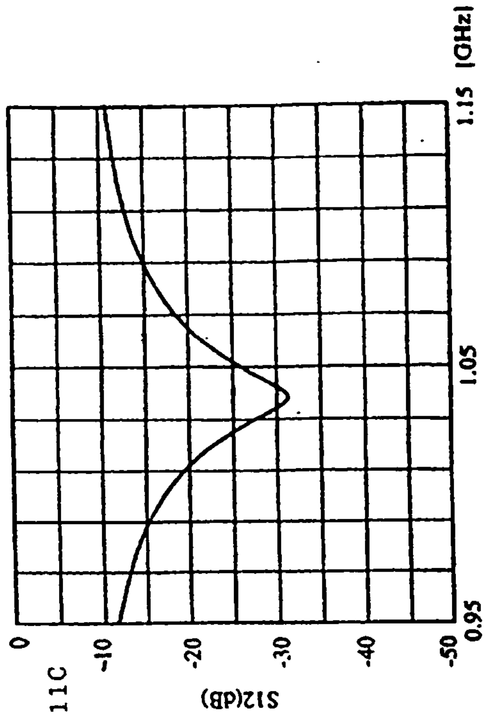


FIG. 11C

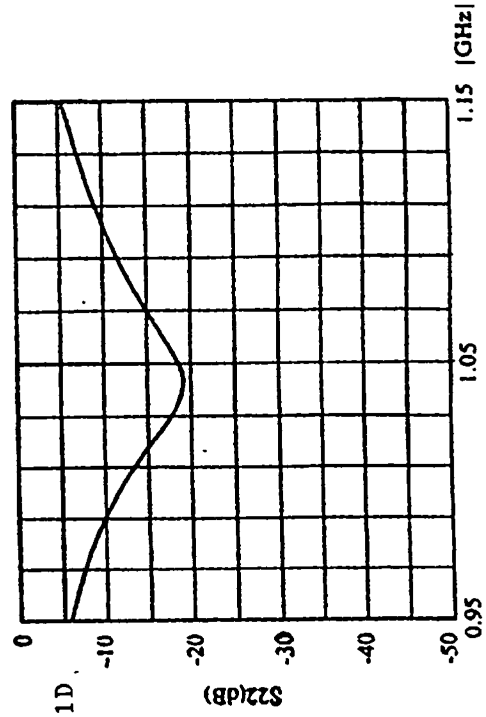


FIG. 11D

FIG. 12A

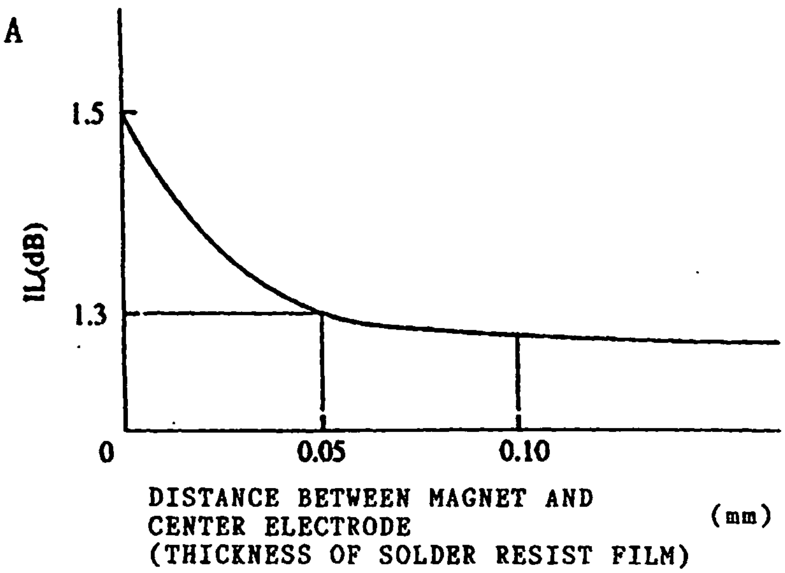


FIG. 12B

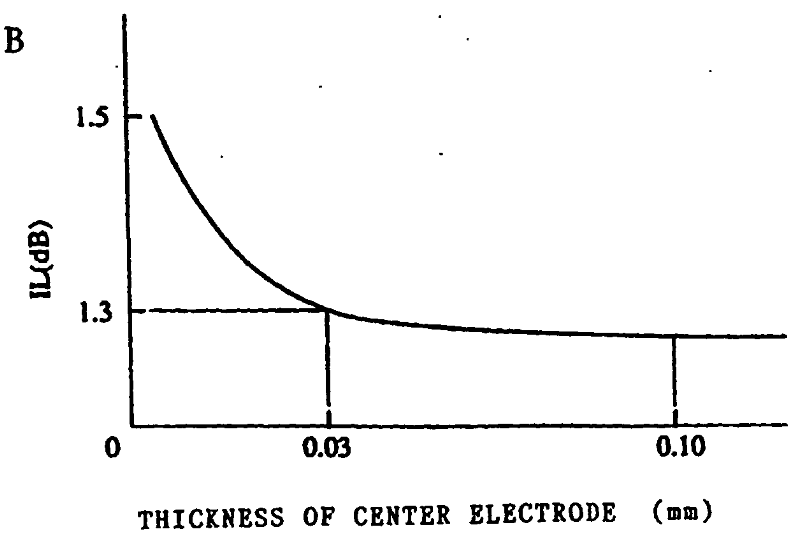


FIG. 13A

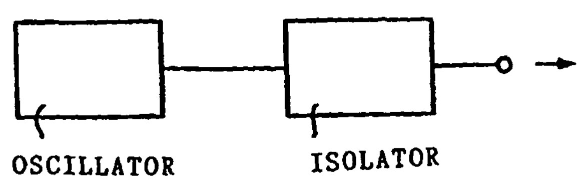


FIG. 13B